OPTICAL INTERFERENCE LAYER FOR ELECTROLUMINESCENT DEVICES

TECHNICAL FIELD

The present invention relates generally to electroluminescent devices and more specifically relates to an electroluminescent device having one or more thin film optical interference layers to reduce reflectance from ambient light.

BACKGROUND ART

Electroluminescent devices (ELDs) are well known and are generally constructed of several layers of different materials. These layers typically consist of a transparent front-electrode layer, an electroluminescent layer and a back-electrode layer. When a voltage is applied across the electrodes, the electroluminescent layer becomes active, converting some portion of the electrical energy passing therethrough into light. This light is then emitted out through the front-electrode where it is visible to a user of the device.

Electroluminescent devices can be particularly useful as computer displays and are generally recognized as high-quality displays for computers and other electronic devices used in demanding applications such as military, avionics and aerospace where features such as high reliability, low weight, and low power consumption are important. Electroluminescent displays are also gaining recognition for their qualities in automotive, personal computer and other consumer industries, as they can offer certain benefits over other displays such as cathode-ray tubes ("CRT") and liquid crystal displays ("LCD").

One feature of electroluminescent displays is the ability to add thin films to vary the characteristics of the display. It is known to use thin film layers in electroluminescent displays to improve selected display characteristics, such as signal-to-reflected-ambient light ratio ("SRA") and contrast ratio ("CR").

One particular type of thin-film layer that can be used to improve contrast ratio in electroluminescent devices is a substantially transparent optical interference layer placed between one or more of the layers of the electroluminescent device, as taught in U.S. Patent 5,049,780 to Dobrowolski.

Using the principle of destructive interference, the optical interference layer can result in the reduction of the amplitude of ambient light by superimposing of two or more, out-of-phase, electromagnetic waves, which can be generated by reflection and/or transmission at the interfaces of thin-film layer(s). By selecting appropriate thicknesses of the layers, optical destructive interference at the electromagnetic wavelengths of interest (typically visible ambient light waves reflected off of the display) can result in an exceptional contrast ratio and/or signal-to-reflected ambient light ratio.

Dobrowolski is generally directed to voltage-driven inorganic electroluminescent devices, where the electroluminescent layer is formed of an inorganic material, and which typically require one or more additional transparent dielectric layers to reduce electrical-breakdown of the inorganic electroluminescent layer. Such inorganic electroluminescent devices are typically voltage-driven, powered with alternating current ("ac") in order to reduce charge build-up within the device. While Dobrowolski does generally contemplate the use of direct current ("dc") electroluminescent devices without transparent dielectric layers, such inorganic devices are still voltage-driven, and are generally prone to electrical breakdown of the electroluminescent layer. Modern, current-driven organic electroluminescent devices can offer certain advantages, such as colour improvements and a reduced barrier to current flow to reduce the necessary drive voltage, when compared to voltage-driven inorganic electroluminescent devices, and as such the teachings of Dobrowolski do not address these issues.

It is known to reduce ambient light on organic electroluminescent devices by placing a filter or other absorbing layers in front of the electroluminescent layer and/or the rear electrode. Such filters can absorb ambient light incident on the device and thus improve the viewing characteristics of the device. Filters do not, however, reduce pixel blooming, whereby emitted light is reflected off the rear of the device and then emitted through the front in such a manner as to cause the appearance of "bloomed" pixels, thus having deleterious effects on the overall display characteristics of the device. However, a certain amount of emitted light is also absorbed by the filter, thus requiring an increased drive current that

brightens the display, and to compensate for the absorbed emitted light and thus reducing the life of the display.

Furthermore, as known to those of skill in the art, both inorganic and organic electroluminescent devices require a passivation layer to protect the layers from moisture and oxygen, as air and water can irreparably damage these layers. A hermetic seal is generally required, as taught in, for example, United States patent 5,811,177. However, the inclusion of such a hermetic seal does not generally improve the contrast ratio and other visual characteristics of the display.

DISCLOSURE OF THE INVENTION

It is therefore an object of the present invention to provide a novel electroluminescent device which obviates or mitigates at least one of the disadvantages of the prior art.

It is another object of the present invention to provide a novel kit for retrofitting an electroluminescent device.

It is yet another object of the present invention to provide a method of fabricating an electroluminescent device.

Accordingly, in one of its aspects, the present invention provides an electroluminescent device for displaying an image to a viewer in front of said device, comprising:

a front electrode substantially transparent to electroluminescent light;

a rear electrode substantially transparent to ambient light;

an electroluminescent layer (e.g., comprising an organic material such as a polymer or a small molecule) disposed between said electrodes; and

an optical interference member for passivating said electroluminescent device and for reducing the reflectance of said ambient light towards said viewer, said member disposed behind said rear electrode.

In another of its aspects, the present invention provides a kit for retrofitting onto an electroluminescent device having a front electrode substantially transparent to electroluminescent light, a rear electrode substantially transparent to ambient light, and an electroluminescent layer disposed between said electrodes, said kit comprising:

an optical interference member formed on a substrate, such that when said optical interference member is affixed behind said rear electrode the reflectance of ambient light towards a viewer is reduced and said device is passivated.

In yet another of its aspects, the present invention provides a method of fabricating an electroluminescent device for displaying an image to a viewer in front of said device, comprising the steps of:

depositing a substantially transparent front electrode onto a substantially transparent substrate;

depositing an electroluminescent layer onto said substrate such that said front electrode is intermediate said electroluminescent layer and said substrate;

depositing a substantially transparent rear electrode onto said substrate such that said front electrode and said electroluminescent layer are intermediate said rear electrode and said front electrode; and,

affixing an optical interference member behind said rear electrode, said optical interference member for passivating said electroluminescent device and for reducing the ambient light reflected towards said viewer.

In yet another of its aspects, the present invention provides an electroluminescent device comprising a front electorde, a rear electrode and a passivating layer, wherein the passivating layer comprises a malleable gel material.

Thus, in one of its preferred aspects, the present invention provides a transparent electroluminescent device having an optical interference member which reduces the overall reflectance from the device. The optical interference member is formed on a substrate, typically comprising a reflective layer, a transparent layer, a semi-transparent layer and an anti-reflective coating. The optical interference member can then be affixed behind the electroluminescent display with a transparent rear electrode. When affixed, the optical interference member can reduce reflectance from ambient light and serve as a passivation layer that protects the elements of the electroluminescent device from exposure to external elements. The optical interference member can increase the reflectance of infra-red ambient light, compared to absorbing films, to thus reduce the overall heating of the display. Furthermore, the optical interference member

can absorb light emitted towards the back of the display from the electroluminescent layer, thus reducing pixel blooming and improving the overall characteristics of the device. In another embodiment of the invention, the passivation layer can be added without the optical interference layer.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will be described with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of a cross-section of a portion of an electroluminescent device in accordance with a first embodiment of the invention, showing an optical interference member exploded therefrom;

Figure 2 is a schematic diagram of a rear view of the optical interference member of Figure 1 having two holes formed therein;

Figure 3 is a schematic cross-sectional view of the optical interference member of Figure 2 placed in a stand used in the preparation of the optical interference member for assembly with the display of Figure 1;

Figure 4 is the schematic cross-sectional view of Figure 3 showing a tube inserted into one of the holes of the optical interference member;

Figure 5 is the schematic cross-sectional view of Figure 4 showing a bead of epoxy deposited about the periphery of the tube;

Figure 6 is a schematic end view of the optical interference member of Figure 5 showing a second tube affixed into the second hole with a bead of epoxy;

Figure 7 is a schematic front view of the optical interference member of Figure 2 having a spacer placed about the periphery;

Figure 8 is a schematic end view of the optical interference member of Figure 7;

Figure 9 is a schematic end view of the optical interference member of Figure 8 being applied to the display of Figure 1;

Figure 10 is a schematic end view of the assembled device shown in Figure 9 having a bead of epoxy applied to the exterior periphery of the spacer;

Figure 11 is an end view of the cavity in the device of Figure 10 being filled with a passivating gel;

Figure 12 is a schematic diagram of a cross-section of through a portion of an electroluminescent device in accordance with another embodiment of the invention, showing an optical interference member exploded therefrom;

Figure 13 is a schematic diagram of a cross-section of through a portion of an electroluminescent device in accordance with another embodiment of the invention, showing a passivating optical interference member exploded therefrom; and

Figure 14 is a schematic diagram of a cross-section of through a portion of an electroluminescent device in accordance with another embodiment of the invention, showing a sealing member exploded therefrom.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring now to Figure 1, an electroluminescent device in accordance with a first embodiment of the invention is indicated generally at 30. Device 30 comprises an electroluminescent display 31 and an optical interference member 50. Electroluminescent display 31 includes a transmitting substrate 32, a transmitting front electrode 34 disposed behind substrate 32, an electroluminescent layer 36 disposed behind electrode 34, and an ambient light transmitting rear electrode 38 disposed behind electroluminescent layer 36. Display 31 is connected to a power supply 40 via front electrode 34 and rear electrode 38 in order to drive a current through electroluminescent layer 36, and causing light L_{em} to be emitted through electrode 34 and substrate 32 and towards a viewer in front of device 30.

Transmitting substrate 32 is made from any suitable material which is transparent to at least a portion of emitted electroluminescent light, such as glass or plastic. A presently preferred material is glass having a thickness of from about 0.5mm to about 5mm. More preferably the glass has a thickness of from about 0.7mm to about 2mm. However, it is presently preferred that the glass has a thickness of about 1.1 mm. A suitable source for such glass is Corning Part #1737F available from Corning Inc. Advanced Display Products, Corning, New

York, 14831. However persons of skill in the art can choose other appropriate materials and thicknesses.

Transmitting electrode34 is any conducting material which is transparent to at least a portion of emitted electroluminescent light, such as indium tin oxide (ITO) or zinc oxide (ZnO). In a present embodiment, where electrode 34 is a layer of indium tin oxide, a presently preferred thickness is about fifteen-hundred angstroms (1500Å).

It is to be understood that electroluminescent transmitting electrode 34 can have different thicknesses, and can be in the range of, for example, from about one-thousand angstroms (1000Å) to about three-thousand angstroms (3000Å), or from about twelve-hundred angstroms (1200Å) to about two-thousand angstroms (2000Å).

Electroluminescent layer 36 can be either an inorganic or organic electroluminescent material. Suitable inorganic materials include ZnS:Mn (Zinc Sulfide doped with Manganese). Other suitable inorganic materials include ZnS:Ho, ZnS:Tb, ZnS:Tr, ZnS:Ag, ZnS:Cu, SrS:Ce, StS:Cu, StS:Cu,Ag. Other multiply-combined dopants or stacked materials will occur to those of skill in the art and as desired to provide different display characteristics, such as colour. (A discussion on such materials can be found in, for example, P.D. Rack, P.H. Holloway, "The Structure, Device Physics, and Material Properties, of Thin Film Electroluminescent Displays." *Materials Science and Engineering R21 (1998)*, 171-219.)

It will be understood that where layer 36 is an inorganic material, then power supply 40 will typically be an alternating current voltage source, and layer 36 will typically be sandwiched between dielectric layers (not shown) that stabilize layer 36 from electrical breakdown. Suitable dielectric materials can include, for example, Al_2O_3, SiO_2, SiON, SiAlON. Other dielectrics will occur to those of skill in the art.

Suitable organic materials include tris(8-hydroxyquinoline aluminum) (Alq3) or poly para phenylene vinylene (PPV). As known by those of skill in the art, photons of light from organic electroluminescent displays are emitted when electrons drop from a lowest unoccupied molecular orbital ("LUMO") of layer

36, where they combine with holes in the highest occupied molecular orbital ("HOMO") of layer 36. Accordingly, a current flow through an organic electroluminescent layer 36 can produce an emission of light. In a present embodiment, layer 36 is organic, preferably made from tris(8-hydroxyquinoline aluminum) and having a thickness of about five-hundred angstroms (500Å), although those of skill in the art will be able to select other appropriate materials and thicknesses of this layer. Where layer 36 is an organic material, then power supply 40 will typically be a constant current source, the polarity of such a current source corresponding to which of electrode 34 and electrode 36 is the cathode and the anode. It will be further apparent to those of skill in the art that the work functions of the cathode and the anode are generally chosen to substantially equal the respective LUMO and HOMO energies levels of organic electroluminescent layer 36.

While not always required, it is presently preferred that, where electroluminescent layer 36 is organic, then an electron transport layer will be situated between electroluminescent layer 36 and the cathode of display 31 and/or a hole transport layer will be situated between electroluminescent layer 36 and the anode of display 31. It will be understood that the work functions of the electron transport layer and the hole transport layer will accordingly be chosen to substantially equal the LUMO and HOMO energy levels of layer 36, respectively. Where electroluminescent layer 36 is made from Alq3, then it is generally preferred that a hole transport layer be situated between layer 36 and the anode of display 31. A suitable material for hole transport layer is NPD having a thickness of about 500Å.. Other suitable materials, for both hole transport layers and electron transport layers include α-NPD, NPB and TPD. Typical thickness can be from about 300Å to about 700Å. Other suitable materials and thickness will occur to those of skill in the art. A discussion of such structures can be found in, for example, H. Nakamura et al, "Late-News Paper: Simple Structures for Blue OLED", 1999, *SID 99 Digest*, p. 446.

Rear electrode 38 is preferably made from a conducting material that is at least partially transparent to ambient light L_{amb} incident upon substrate 32 and passing through device 30. Suitable conducting materials include aluminum or

indium tin oxide. A presently preferred material is indium tin oxide. The indium tin oxide can have a thickness of from about 500Å to about 2000Å. A presently preferred thickness is about 1000Å. As known to those of skill in the art, in the case of organic displays it is generally preferred to include a thin layer of a low work function material, such as a suitable metal, as part of the rear electrode. However, it will occur to those of skill in the art that other suitable materials and thicknesses can be chosen and used, and such variations are within the scope of the invention.

In the present embodiment, layers 34, 36 and 38 are successively vacuum deposited onto substrate 32. Where layer 36 is inorganic, the previously-described dielectric layers would also be deposited in their appropriate sequence. Similarly, where layer 36 is organic, the previously-described electron transport layer and hole transport layer would also be deposited in their appropriate sequence. Collectively, layers 32, 34, 36, and 38 compose electroluminescent display 31. Other suitable substrates and means of fabricating display 31 will occur to those of skill in the art. For example, where electroluminescent layer 36 is PPV, then spin-coating can be an appropriate fabrication technique for layer 36.

Device 30 also includes an optical interference member 50 which is attachable behind rear electrode 38 . The details of the attachment will be discussed in greater detail below.

In a present embodiment, optical interference member 50 is separately formed for attachment to display 31 behind rear electrode 38. Optical interference member 50 comprises an anti-reflective coating layer 54 of silicon dioxide, having a thickness of about nine-hundred-and-fifty angstroms (950Å). A semi-absorbent layer 58 is disposed behind anti-reflective coating layer 54. Semi-absorbent layer 58 is partially reflective, partially absorbing and partially transmissive of light in the visible spectrum, and in a present embodiment, is made from Inconel having a thickness of about one-hundred angstroms (100Å). Other suitable materials can include Nickel (Ni), Titanium, or a suitable organic material and appropriate thicknesses of such layers can be determined by those of skill in the art.

The extinction coefficient of the material and its thickness should be selected so that the reflection from layer 58 at a preselected wavelength, neglecting optical interference, should preferably be at least about thirty-five percent, with the remainder of light energy being absorbed and dissipated in the form of heat. Similarly, transmission through layer 58 at a preselected wavelength, neglecting optical interference, will preferably be at least about thirty-five percent.

It is to be understood that the extinction coefficient of layer 58 and its thickness can be selected so that the transmission through layer 58 at a preselected wavelength, neglecting optical interference, can be from about thirty percent to about forty percent. Overall, the amount of light transmitted through layer 58, after two passes, should be substantially equal to the amount of light that is originally reflected from layer 58, in order to achieve the appropriate destructive interference at the reflective surface of layer 58, as will be understood by those of skill in the art.

A substantially transparent layer 62 is disposed behind layer 58. Substantially transparent layer 62 is made from silicon dioxide (SiO_2) having a thickness of about seven-hundred-and-fifty angstroms (750Å). Other suitable layer thicknesses can be used as will occur to those of skill in the art. Other suitable materials include, for example, Silicon Nitride (Si_2N_3) and zinc oxide (ZnO). The extinction coefficient of the material of layer 62 and its thickness is selected so that the transmission through layer 62 at a preselected wavelength, neglecting optical interference, is greater than about eighty percent, but is preferably at least about ninety percent. As known to those of skill in the art, it is generally preferred that the preselected wavelength(s) for layer 62 should be substantially equal to the preselected wavelengths used to choose layer 58.

A reflective layer 66 is disposed behind layer 62. Reflective layer 66 is preferably made from aluminum and has a thickness of about fifteen-hundred angstroms (1500Å). Other suitable materials and thickness will occur to those of skill in the art.

Finally, a substrate 70, made from a material such as glass or plastic is disposed behind reflective layer 66. As will now be apparent, member 50 is

formed by successively depositing layers 66, 62, 68 and 64 onto substrate 70 using a technique such as vacuum deposition.

A wavelength of about five-hundred-and-fifty-five nanometers (555nm), substantially at the centre of the spectrum of visible light, is a presently preferred preselected wavelength used for the purpose of determining appropriate thicknesses and materials of layers member 50, as the assembled device 30 can have the desired optical interference characteristics across the visible light spectrum. As will be understood by those of skill in the art, an incidental benefit to the selection of this wavelength can result in a device which reflects electromagnetic energy outside the visible spectrum, including infra-red, thus reducing the heating of the display. However, it will occur to those of skill in the art that other wavelengths can be selected, as desired.

Member 50 can be assembled onto display 31 using techniques known in the art. However, a presently preferred and novel method of assembly is as follows. As shown in Figure 2, member 50 includes two holes 80, 82, about 1/8" inches in diameter. Holes 80, 82 are preferably formed in substrate 70 prior to the deposition of the layers 66, 62, 58 and 54 thereon, and during deposition, holes 80, 82 remain unoccluded. Referring now to Figure 3 member 50 is placed over a template 84 having a hole 86 which is aligned with hole 80. Template 84 is preferably a clean piece of glass positioned in a tray 88 in sized to snugly retain template 84 therein. (Together, template 84 and tray 88 compose a stand.) Next, a guide-wire 90 or wire-stand or wire-rack is placed through holes 80 and 86 so that it rests on the bottom of tray 88.

Referring now to Figure 4, a tube 92 made from vinyl, having a length of about three inches and an external diameter smaller than the diameter of hole 80 is inserted into holes 80 and 86 so that the end of tube 92 rests against the bottom of tray 88. Accordingly, the thickness of template 84 determines the length of tube 92 that extends past optical interference layer 54.

Referring now to Figure 5, a small bead of epoxy 94 is placed about the periphery of tube 92 at the junction thereof and the periphery of hole 80 to form seal and affix tube 92 in hole 80. A presently preferred epoxy is Dymax UV curing epoxy Part Number 9005, 51 Greenwoods Road, Torrington, CT, 06790,

USA but other sealants will occur to those of skill in the art. The bead of epoxy 94 is then exposed to ultraviolet light in order to cure the epoxy. The foregoing steps are repeated, or performed simultaneously, to seal and affix a second tube 96 within hole 82, as shown in Figure 6.

In an alternative embodiment, tubes 92, 96 have the same inner diameter as holes 80, 82, respectively, and are affixed thereto by placing a bead of epoxy around the base of tubes 92, 96 when they abut the periphery of their respective holes 80, 82. In this alternative embodiment, template 84 can be eliminated.

Next, the mating surfaces of electrode 38 and substrate 54 are prepared by applying a primer to each respective surface. A suitable primer is Primer 94 available from 3M Canada, 155 Les Mill Road, North York, Ontario, M3B 2T8, Canada. The mating surfaces of electrode 38 and substrate 54 are then allowed to dry, usually for a period of about five minutes. Compressed nitrogen can be used to clean both of the mating surfaces.

Referring now to Figures 7 and 8, spacer 44 is then applied about the periphery of the front face of substrate 54, as best seen in Figure 3. It is presently preferred that spacer 44 is a double-sided tape sold as 3M-Scotch Part Number 4929 also available from 3M Canada. This tape can be trimmed on a clean surface using a stainless steel knife. A presently preferred width of tape is less than about 1.6 millimeters however, other widths can be chosen as desired. As shown in Figure 8, the thickness of spacer 44 is preferably about 0.05 inches. (In a present embodiment, spacer 44 is slightly ticker than template 84, and thus the thickness of spacer 44 can be used to determine an appropriate thickness for template 84).

Next, the protective backing on spacer 44 is removed. Next, member 50 is aligned with electrode 38 and abutted thereagainst, as shown in Figure 9. Gentle pressure can be applied around the edges of member 50 by pressing against substrate 70 to attach member 50 to electrode 38 by allowing the adhesive on spacer 44 to properly adhere itself to electrode 38.

Referring now to Figure 10, sealant 42 is place about the periphery of spacer 44. A presently preferred sealant 42 is an epoxy such as Dymax UV curing epoxy Part Number 9005. Preferably the bead of epoxy is about 1.27 millimeters

wide and is at least thick enough to cover spacer 44, but does not exceed the thickness of member 50 if it should run along the exterior thereof. It is preferable that the bead of epoxy does not contact the electrical contacts on the periphery of display 31. The epoxy can be cured by exposing it to ultraviolet light.

The cavity between electrode 38 and layer 54 is filled with a transparent passivation material such as a silicone gel or silicone oil that is transparent to ambient light. A presently preferred passivation material is a silicone gel. A presently preferred silicone gel is Part Number RTV6166, having two parts, designated as Part A and Part B, which is available from General Electric Corporation 260 Hudson River Road, Waterford, New York, NY, 12188(It is understood that other two-part silicone gels from General Electric can be used). The steps to fill the cavity with the gel are described as follows. First, a sufficient amount gel to fill the cavity is decanted into a beaker. In the present embodiment, Part A and Part B are decanted and then mixed together. Next, the beaker and the assembly of display 31 and member 50 are placed into a desiccator or vacuum chamber. The chamber is then evacuated to create a vacuum therein, preferably until an atmospheric pressure of about 30 Torr is reached. The vacuum is maintained for about fifteen minutes to de-air the gel and desicate and the assembly of display 31 and member 50. The chamber is then vented with nitrogen.

The beaker and the assembly of display 31 and member 50 are then removed from the chamber. Next, as shown in Figure 11, a syringe is filled with the de-aired gel and then used to dispense the gel into tube 92. Dispensing is preferably performed by orienting tube 92 directly above tube 96, to allow gravity to carry the gel towards the corner proximal tube 96. During filling, tube 96 acts as a vent to allow atmosphere displaced by the gel to escape therethrough. It is generally preferred that once the gel approaches the corners, filling is stopped until the gel settles. The filling process is repeated until tube 96 is filled.

The gel is then allowed to cure for a predetermined period of time, preferably about two hours. Next, a piece of indium wire is inserted into each tube 92, 96, and using a wire rack it is pressed down upon to firmly ensure it is

flatted to the glass surface, thereby sealing the hole 80, 82 respective to each tube 92, 96.

In the alternative embodiment, where the tube is sealed in abutment with the periphery of the hole, then the tube is cut flush with the hole, and then a slide of glass is placed over the hole which is sealed with epoxy.

Each tube 92, 96 is then cut flush with substrate 70. Holes 80, 82 are then sealed, preferably by using a drop of epoxy, and then covering each hole 80, 82 with a small piece of cover glass, and then an additional bead of epoxy is placed over the glass. The freshly applied epoxy is then cured under ultra-violet light for about two minutes or any other suitable time. Excess epoxy protruding from the back of substrate 80 can be removed with a razor blade.

The operation of device 30, as fully assembled, will now be discussed. It will be appreciated by those of skill in the art that the following is a simplified model for purposes of explanation, and that other physical phenomena occurring during the operation of device 30 are assumed, for the purposes of this discussion, to have a negligible influence on the operation. Power supply 40 is 'on', so the electricity flows through electroluminescent layer 36 causing light to be emitted out through the front of device 30 through electrode 34, substrate 32 and towards a viewer, as indicated by arrow L_{em}.

At the same time, ambient light is incident upon device 30, as indicated by arrow L_{amb} and passes through substrate 32, electrode 34, electroluminescent layer 36, electrode 38, the gel filling the cavity behind electrode 38, and then through anti-reflective coating 54. Ambient light L_{amb} incident upon semi-absorbing layer 58 is partially reflected, partially absorbed and partially transmitted. The light transmitted through semi-absorbing layer 58 passes through transparent layer 62, where it reflects off reflecting layer 66 and back through transparent layer 62, at which point this reflected light is inverted one-hundred-and-eighty degrees out of phase with the partially reflected light from layer 58, and thus these two reflections destructively interfere and substantially cancel each other out. The energy otherwise found in these two reflections is absorbed by semi-absorbing layer 58 and reflective layer 66, where it is dissipated as a relatively small amount of heat. The result is that reflected light (L_{ref}) back

towards the viewer from device 30 is reduced. In a present embodiment, reflected light (L_{ref}) is reduced by about ninety percent, compared to an electroluminescent device assembled without optical interference member 50.

It is believed that in other embodiments of the invention, reflected light (L_{ref}) can be reduced by as much as about 99.5 percent by choosing different materials, thicknesses and extinction coefficients for optical interference member 50 and by selected appropriate thicknesses and materials for the other layers in device 30.

In other embodiments of the invention, optical interference member 50 can be disposed in combination with other optical interference members incorporated into device 30, such as the structures taught in U.S. Patent 5,049,780 to Dobrolowoski and/or applicant's copending application entitled "Organic Electroluminescent Device", bearing application number 09/361137, the contents of which are incorporated herein by reference.

Referring now to Figure 12, a device in accordance with a second embodiment of the invention is indicated generally at 130. Like components in device 130 to components in device 30 are indicated with the reference numbers that have been increased by a value of 100. Device 130 comprises an electroluminescent display 131 and an optical interference member 150. Electroluminescent display 131 includes an electroluminescent transmitting substrate 132, an electroluminescent transmitting front electrode 134 disposed behind substrate 132, an electroluminescent layer 136 disposed behind electrode 134, and an ambient light transmitting rear electrode 138 disposed behind electroluminescent layer 136. Display 131 is connected to a power supply 140 via front electrode 134 and rear electrode 138 in order to drive a current through electroluminescent layer 136, and causing light L_{em} to be emitted though electrode 134 and substrate 132 and towards a viewer in front of device 130. As will now be apparent to those of skill in the art, display 131 is substantially the same as display 31, and accordingly, the same discussions apply to display 131.

Device 130 also includes an optical interference member 150 which is attachable behind rear electrode 138 . In a present embodiment, optical interference member 150 is separately formed for attachment to display 131

behind rear electrode 138. Optical interference member 150 comprises an anti-reflective coating layer 154 of silicon dioxide, having a thickness of about nine-hundred-and-fifty angstroms (950Å). A substrate 170, made from a material such as glass or plastic is disposed behind ani-reflective coating layer 154.

A semi-absorbent layer 158 is disposed behind substrate 170. Semi-absorbent layer 158 is partially reflective, partially absorbing and partially transmissive of light in the visible spectrum, and in a present embodiment, is made from Inconel having a thickness of about one-hundred angstroms (100Å). Other suitable materials can include Nickel (Ni), Titanium (Ti), or a suitable organic material and appropriate thicknesses of such layers can be determined by those of skill in the art.

The extinction coefficient of the material and its thickness should be selected so that the reflection from layer 158 at a preselected wavelength, neglecting optical interference, should preferably be at least about thirty-five percent, with the remainder of light energy being absorbed and dissipated in the form of heat. Similarly, transmission through layer 158 at a preselected wavelength, neglecting optical interference, will preferably be at least about thirty-five percent.

It is to be understood that the extinction coefficient of layer 158 and its thickness can be selected so that the transmission through layer 158 at a preselected wavelength, neglecting optical interference, can be from about thirty percent to about forty percent. Overall, the amount of light transmitted through layer 158, after two passes, should be substantially equal to the amount of light that is originally reflected from layer 158, in order to achieve the appropriate destructive interference at the reflective surface of layer 158, as will be understood by those of skill in the art.

A substantially transparent layer 162 is disposed behind layer 158. Substantially transparent layer 162 is made from silicon dioxide (SiO_2) having a thickness of about seven-hundred-and-fifty angstroms (750Å). Other suitable materials and layer thicknesses can be used as will occur to those of skill in the art, such as Si_2N_3 and ZnO. The extinction coefficient of the material of layer 162 and its thickness is selected so that the transmission through layer 162 at a

preselected wavelength, neglecting optical interference, is greater than about eighty percent, but is preferably at least about ninety percent. As known to those of skill in the art, it is generally preferred that the preselected wavelength(s) for layer 162 should be substantially equal to the preselected wavelengths used to choose layer 158.

A reflective layer 166 is disposed behind layer 162. Reflective layer 166 is preferably made from aluminum and has a thickness of about fifteen-hundred angstroms (1500Å). Other suitable materials and thickness will occur to those of skill in the art.

As will now be apparent, member 150 is formed by successively depositing layer 154 on a first side of substrate 170 and successively depositing layers 158, 162 and 166 on the opposite side of substrate 170 using a technique such as vacuum deposition.

As will now be apparent to those of skill in the art, the assembly of optical interference member 150 to device 131 is substantially the same as previously described for device 30. Similarly, the variations of structure, assembly and operation of device 30 are also applicable to device 130 with appropriate modifications.

Referring now to Figure 13, a device in accordance with a second embodiment of the invention is indicated generally at 230. Like components in device 230 to components in device 30 are indicated with the reference numbers that have been increased by a value of 200. Device 230 comprises an electroluminescent display 231 and an optical interference member 250. Electroluminescent display 231 includes an electroluminescent transmitting substrate 232, an electroluminescent transmitting front electrode 234 disposed behind substrate 232, an electroluminescent layer 236 disposed behind electrode 234, and an ambient light transmitting rear electrode 238 disposed behind electroluminescent layer 236. Display 231 is connected to a power supply 240 via front electrode 234 and rear electrode 238 in order to drive a current through electroluminescent layer 236, and causing light L_{em} to be emitted though electrode 234 and substrate 232 and towards a viewer in front of device 230. As will now be apparent to those of skill in the art, display 231 is substantially the

same as display 31, and accordingly, the same discussions substantially apply to display 231.

Device 230 also includes a passivating optical interference member 250 which is attachable behind rear electrode 238. Optical interference member 250 comprises a passivation layer 280, which in a present embodiment is layer 154 of silicon dioxide (SiO_2), having a thickness of from about 500Å to about 2000Å. More preferably, layer 154 can be from 750Å about 1250Å. It is presently preferred, however, that layer 154 is about 1000Å.

A semi-absorbent layer 258 is disposed behind passivation layer 280. Semi-absorbent layer 258 is partially reflective, partially absorbing and partially transmissive of light in the visible spectrum, and in a present embodiment, is made from Inconel having a thickness of about one-hundred angstroms (100Å). Other suitable materials can include Nickel (Ni), Titanium (Ti), or a suitable organic material and appropriate thicknesses of such layers can be determined by those of skill in the art.

The extinction coefficient of the material and its thickness should be selected so that the reflection from layer 258 at a preselected wavelength, neglecting optical interference, should preferably be at least about thirty-five percent, with the remainder of light energy being absorbed and dissipated in the form of heat. Similarly, transmission through layer 258 at a preselected wavelength, neglecting optical interference, will preferably be at least about thirty-five percent.

It is to be understood that the extinction coefficient of layer 258 and its thickness can be selected so that the transmission through layer 258 at a preselected wavelength, neglecting optical interference, can be from about thirty percent to about forty percent. Overall, the amount of light transmitted through layer 258, after two passes, should be substantially equal to the amount of light that is originally reflected from layer 258, in order to achieve the appropriate destructive interference at the reflective surface of layer 258, as will be understood by those of skill in the art.

A substantially transparent layer 262 is disposed behind layer 258. Substantially transparent layer 262 is made from silicon dioxide (SiO_2) having a

thickness of about seven-hundred-and-fifty angstroms (750Å). Other suitable materials and layer thicknesses can be used as will occur to those of skill in the art, such as Si_2N_3 and ZnO. The extinction coefficient of the material of layer 262 and its thickness is selected so that the transmission through layer 262 at a preselected wavelength, neglecting optical interference, is greater than about eighty percent, but is preferably at least about ninety percent. As known to those of skill in the art, it is generally preferred that the preselected wavelength(s) for layer 262 should be substantially equal to the preselected wavelengths used to choose layer 258.

A reflective layer 266 is disposed behind layer 262. Reflective layer 266 is preferably made from aluminum and has a thickness of about fifteen-hundred angstroms (1500Å). Other suitable materials and thickness will occur to those of skill in the art.

As will now be apparent, member 250 is formed by successively depositing layers 280, 258, 262 and 266 onto electrode 238, using a technique such as vacuum deposition. In a present embodiment, layers 280, 258, 262, 266 of optical interference member 250 are successively deposited behind rear electrode 238. It is contemplated that such deposition can be performed as part of the deposition required to build display 231, or the deposition can be performed as a completely separate stage of the assembly of device 230. For example, display 231 can be formed and then packaged in a sealed chamber for shipping to another location, where display 231 can then be removed and at which point optical interference member 250 can be formed thereon.

As will now be apparent to those of skill in the art, the operation of device 230 is substantially the same as previously described for device 30. Similarly, the variations of structure and operation of device 30 are also applicable to device 230 with appropriate modifications. It is believed that in the present embodiment however, up to about 95% of unwanted ambient light reflection is eliminated.

In a variation of device 230, passivation layer 280 can be eliminated where the patterning, materials and thicknesses chosen for optical interference member 250 correspond to the electrical properties of electrode 238, and accordingly optical interference member 250 can thus form part of the electrical

circuit that power electroluminescent layer 236. Other variations will occur to those of skill in the art.

Referring now to Figure 13, a device in accordance with another embodiment of the invention is indicated generally at 330. Like components in device 330 to components in device 30 are indicated with the reference numbers that have been increased by a value of 300. Device 330 comprises an electroluminescent display 331 and an optical interference member 350. Electroluminescent display 331 includes an electroluminescent transmitting substrate 332, an electroluminescent transmitting front electrode 334 disposed behind substrate 332, an electroluminescent layer 336 disposed behind electrode 334, and a rear electrode 338 disposed behind electroluminescent layer 236. Display 331 is connected to a power supply 340 via front electrode 334 and rear electrode 338 in order to drive a current through electroluminescent layer 336, and causing light L_{em} to be emitted though electrode 334 and substrate 332 and towards a viewer in front of device 330. As will now be apparent to those of skill in the art, display 331 is substantially the same as display 31, and accordingly, the same discussions substantially apply to display 331. However, in addition to the previously described variations on display 31, display 331 can have a rear electrode 338 that is either transparent or reflective.

Sealing member 351 is a separate attachment to display 331 behind rear electrode 338. In a present embodiment, sealing member 351 comprises a substrate 370, made from a material such as glass or plastic. Sealing member 351 is assembled onto display 331 in substantially the same manner that optical interference member 50 is assembled to display 31 in device 30. In particular aspect of the present embodiment, a gel is used to fill the cavity between member 351 and electrode 338 and act as a passivating layer for electrode 338. It will now be apparent that, while sealing member 351 does not have the same contrast enhancement features of the previous embodiments, it retains a passivation layer of gel for display 331.

While only specific combinations of the various features and components of the present invention have been discussed herein, it will be apparent to those of skill in the art that desired sub-sets of the disclosed features and components

and/or alternative combinations of these features and components can be utilized, as desired. For example, the embodiments discussed herein can be combined to provide multiple optical interference members disposed between different layers of the electroluminescent device, and therefore disjoined from each other, in order to further reduce reflectance from the device.

Furthermore, the optical interference members described in the embodiments herein can simply be a transparent layer instead of a combination of a transparent layer and a semi-absorbing layer in order to achieve different results, and it will be apparent that these different types of optical interference members can also be placed at different locations throughout the device.

The present invention can be suitable for a computer display. For example, a pixellated electroluminescent computer display can be formed where the front electrode comprises a plurality of generally parallel and spaced electrodes to compose the front layer of an electroluminescent computer display, and the rear electrode comprises a number of spaced cathodes which are generally perpendicular to the front electrodes. It will be further understood that the electrodes can be patterned in a variety of ways, other than pixellated, to create different recognizable patterns to a user of device 10. When such a display has an organic electroluminescent layer and is pixellated or patterned, it will be appreciated that individual pixels or patterns can be fired using known techniques such as pulsed-DC, and/or adding a periodic reverse-polarity 'refresh' pulse to reduce built-up charge. The device can also be hybrid-display having an active matrix, as can be found in notebook computers.

In addition, the present invention can be suitably modified for use in colour electroluminescent devices. As known to those of skill in the art, multi-colour and full-colour devices can be formed from stacked transparent organic electroluminescent layers. Multi-coloured and full-coloured devices can also be provided through a patterned red-green-blue organic layer (i.e. by selecting materials having inherent colour properties, or by appropriately doping the patterns on the layer). Other colourizing techniques can including the use of a white-emitter and appropriate filters. Alternatively, a blue emitter in combination with colour-change materials can be used. It will be apparent that the teachings

of the present invention can be modified to accommodate these and other colour devices.

The present invention can be suitable for use as a backlight for a liquid crystal display, having the optical interference member disposed therebehind.

The present invention provides a novel electroluminescent device having an optical interference member which reduces the overall reflectance from the device. The optical interference member is provided in the form of a kit that can be retrofitted onto the back of an existing electroluminescent device. When affixed, the kit can provide reduce reflectance from ambient light and serve as a passivation layer that protects the elements of the electroluminescent device from exposure to external elements. Preferably, the components of the optical interference member are selected to have a thickness which causes at least some destructive optical interference of ambient light incident on the electroluminescent display. Finally, in embodiments where a semi-absorbent layer and transparent layer are combined to form the optical interference member, then placement of such an optical interference member can actually increase the reflectance of infra-red ambient signatures, compared to absorbing films, thus reducing the heating of the display and reducing the likelihood of damage to the electroluminescent layer.

While the present invention has been described with reference to preferred and specifically illustrated embodiments, it will of course be understood by those skilled in the arts that various modifications to these preferred and illustrated embodiments may be made without departing from the spirit and scope of the invention.

All publications, patents and patent applications referred to herein are incorporated by reference in their entirety to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated by reference in its entirety.